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Liu et al.

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(54) **EFFICIENT ANNOTATION OF LARGE SAMPLE GROUP**

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G06N 20/10 (2019.01)
(Continued)

(52) **U.S. Cl.**

CPC ***G06N 20/00*** (2019.01); ***G06F 16/23*** (2019.01); ***G06F 16/24554*** (2019.01);
(Continued)

(58) **Field of Classification Search**

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(Continued)

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Assistant Examiner — Randall K. Baldwin
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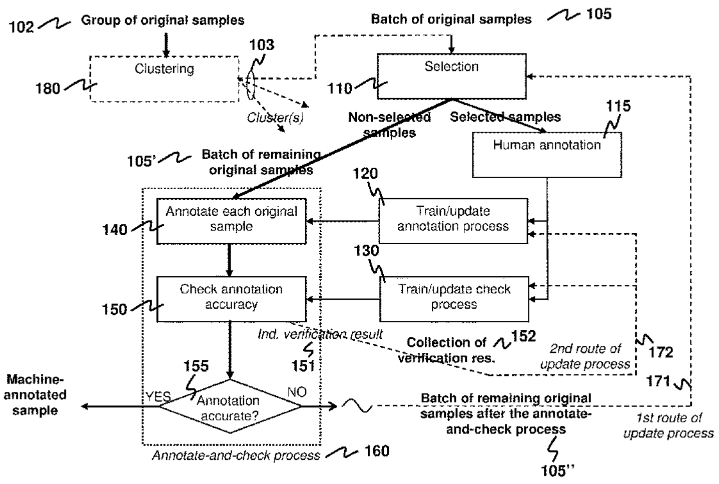
(57) **ABSTRACT**

A method for annotating a batch of original samples is provided. A first subset of original samples, selected from the batch and determined by minimizing an entropy-mean difference between the first subset and the batch, is used for human annotation to yield human-annotated samples. The human-annotated samples are used as training data to configure an annotation process for annotating an input sample to yield an annotated output sample, and a check process for verifying annotation accuracy of the annotated output sample. Remaining original samples in the hatch are processed by the annotation process to yield machine-annotated samples, whose accuracy is verified by the check process. In one embodiment, part of the original samples corresponding to erroneous machine-annotated samples are selected for human annotation. Resultant additional human-annotated

(Continued)


102
Group of original samples
Batch of original samples
105
103
Clustering
180
Selection
110
Cluster(s)
Non-selected samples
Selected samples
115
Human annotation
105'
Batch of remaining original samples
120
Annotate each original sample
Train/update annotation process
140
130
Check annotation accuracy
Train/update check process
150
Ind. verification result
151
Collection of verification res.
152
2nd route of update process
172
155
Machine-annotated sample
YES
Annotation accurate?
NO
171
Batch of remaining original samples after the annotate-and-check process
1st route of update process
Annotate-and-check process
160
105''

samples are used to update the two processes. The remaining original samples not yet annotated are then processed by the two processes.

19 Claims, 3 Drawing Sheets

(51) **Int. Cl.**

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G06F 16/28	(2019.01)
G06F 16/2455	(2019.01)
G06F 16/2457	(2019.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
CPC G06F 17/30525; G06F 17/30598; G06F 17/30722; G06F 17/30752; G06K 9/62; G06K 9/6223; G06N 99/00; G06N 99/005; G06N 20/00; G06N 20/10; G06N 3/02
See application file for complete search history.

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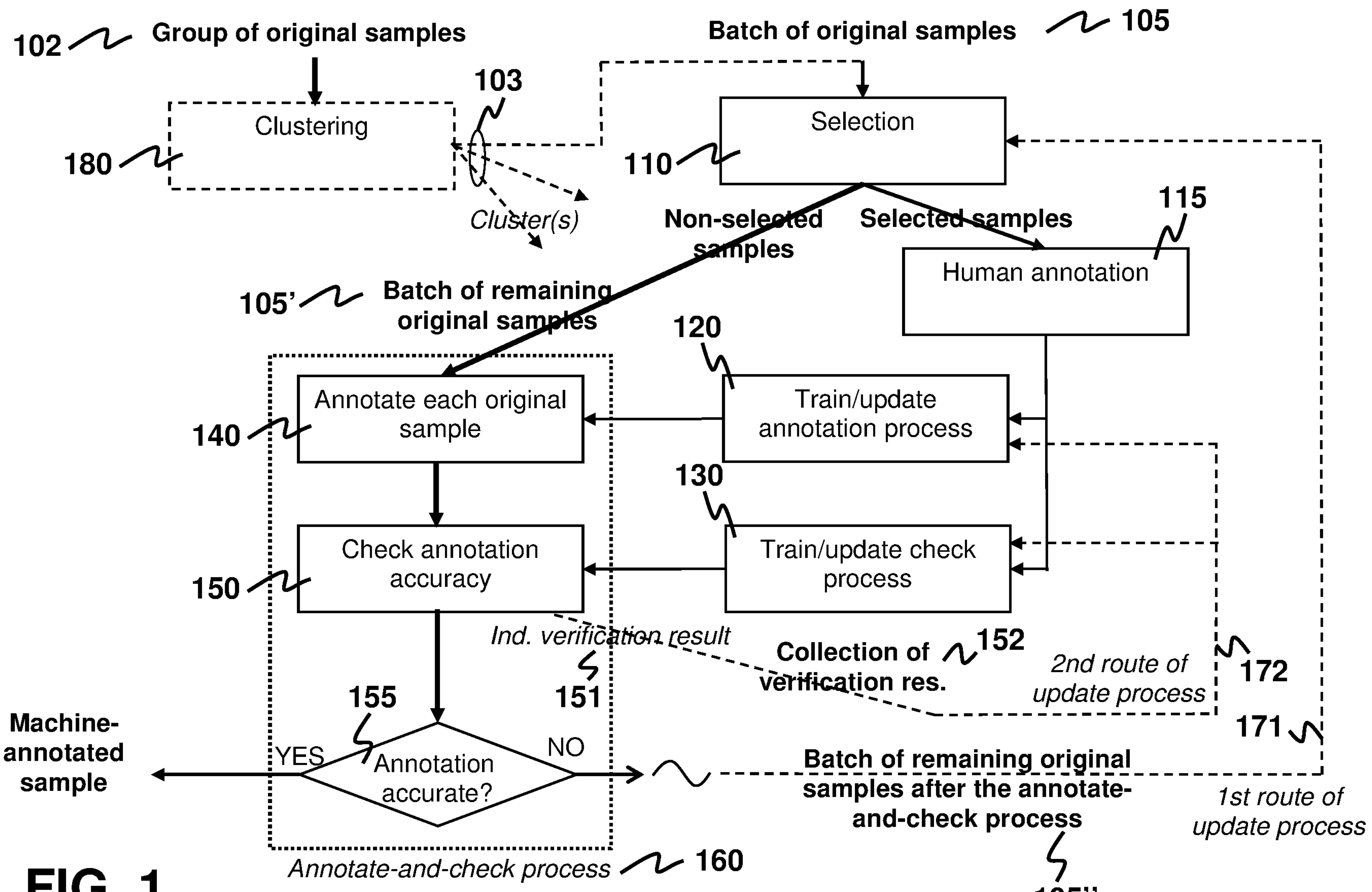
102
Group of original samples
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Cluster(s)
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Human annotation
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Train/update annotation process
Annotate each original sample
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130
Train/update check process
Check annotation accuracy
150
Ind. verification result
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Collection of verification res.
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2nd route of update process
172
155
Machine-annotated sample
YES
Annotation accurate?
NO
171
Batch of remaining original samples after the annotate-and-check process
1st route of update process
Annotate-and-check process
160
105''

FIG. 1

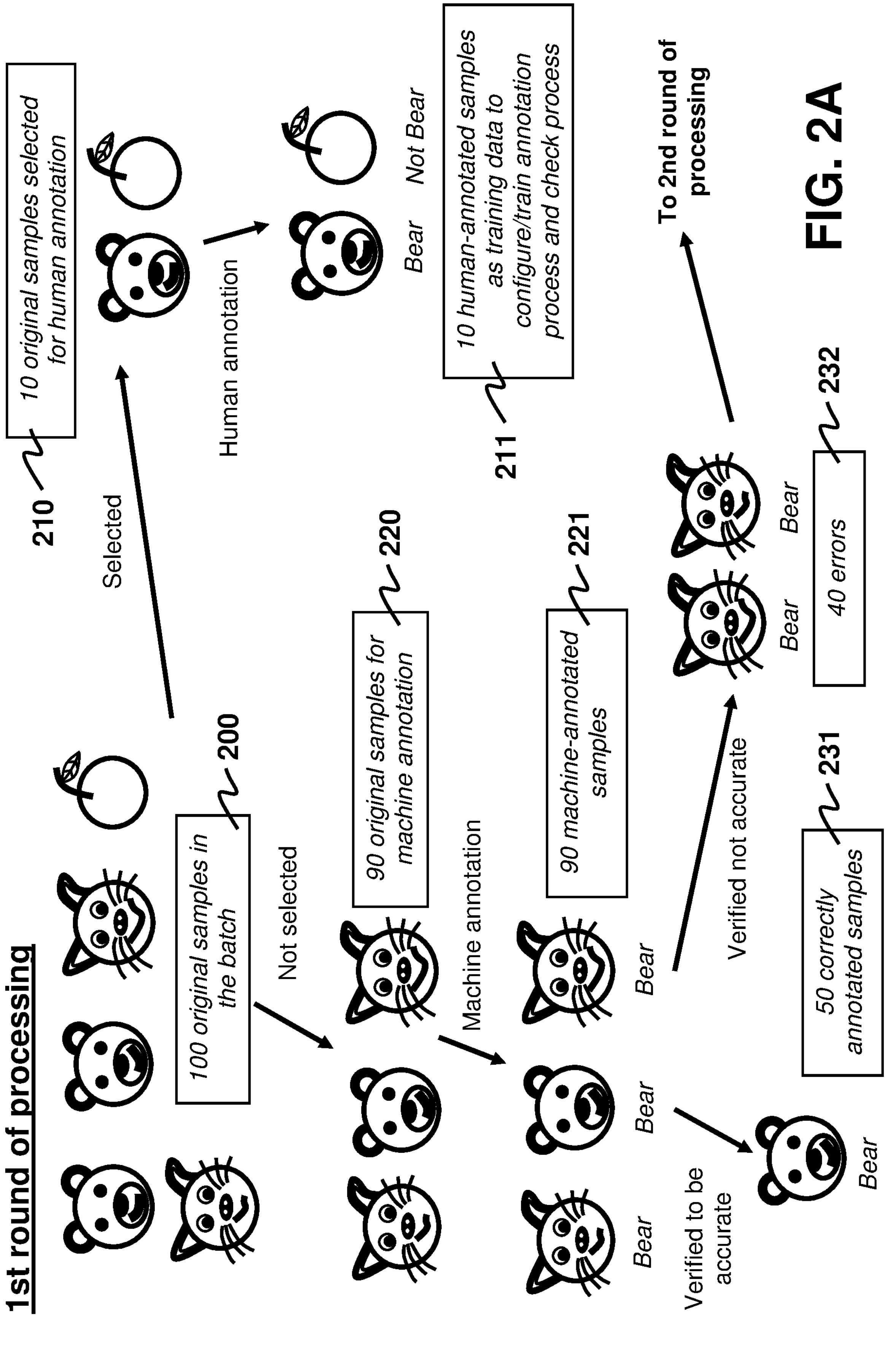
1st round of processing
100 original samples in the batch
200
Selected
Not selected
10 original samples selected for human annotation
210
Human annotation
Bear
Not Bear
10 human-annotated samples as training data to configure/train annotation process and check process
211
90 original samples for machine annotation
220
Machine annotation
90 machine-annotated samples
221
Bear
Bear
Bear
Verified to be accurate
Verified not accurate
Bear
50 correctly annotated samples
231
Bear
Bear
40 errors
232
To 2nd round of processing

FIG. 2A

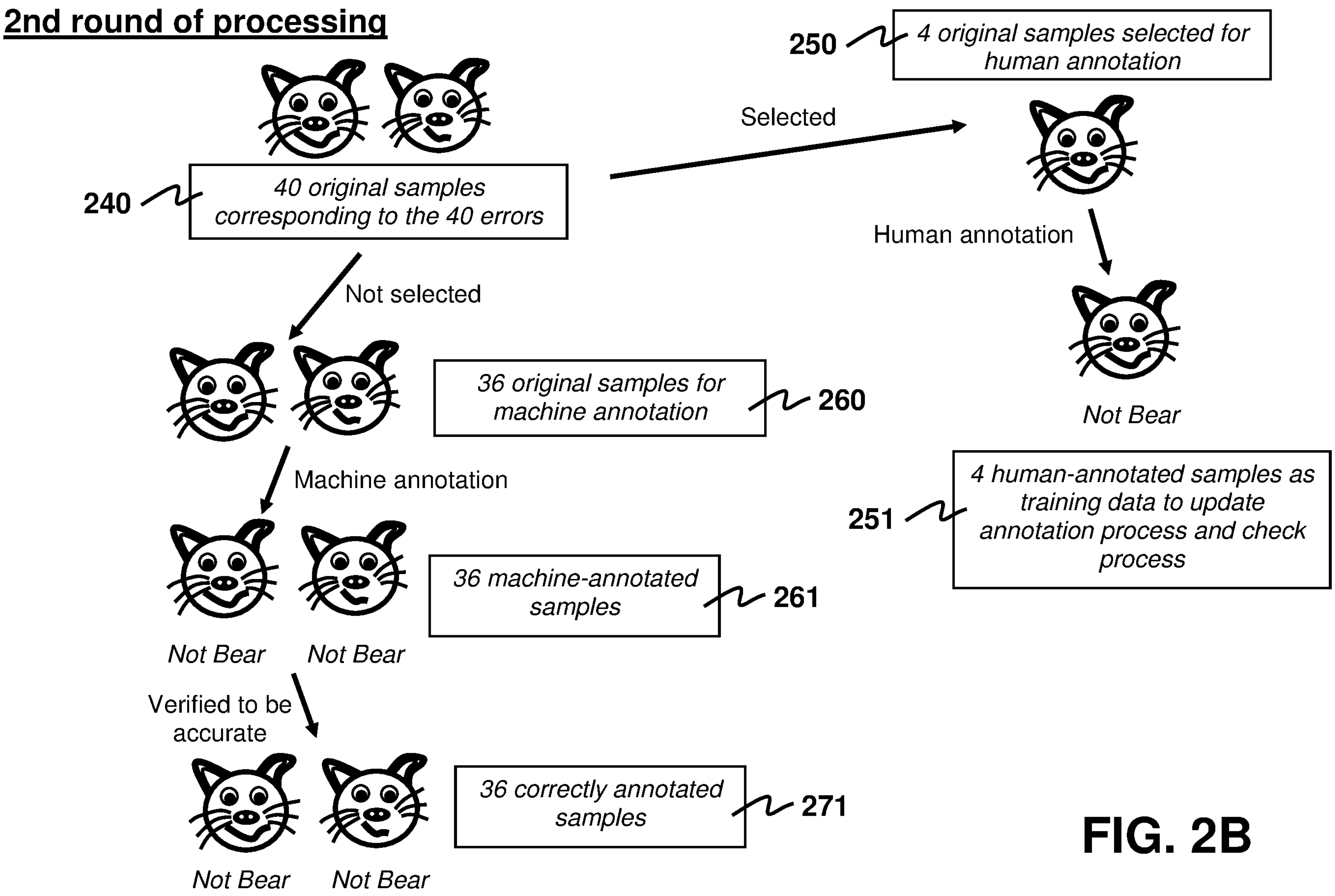
2nd round of processing
240
40 original samples corresponding to the 40 errors
Selected
250
4 original samples selected for human annotation
Human annotation
Not Bear
251
4 human-annotated samples as training data to update annotation process and check process
Not selected
36 original samples for machine annotation
260
Machine annotation
36 machine-annotated samples
261
Not Bear
Not Bear
Verified to be accurate
36 correctly annotated samples
271
Not Bear
Not Bear

FIG. 2B

EFFICIENT ANNOTATION OF LARGE SAMPLE GROUP

FIELD OF THE INVENTION

The present invention generally relates to a computer-implemented method for annotating a batch of samples. In particular, the present invention relates to such method where human annotation is used in annotating base cases and special cases among the samples while remaining samples are machine-annotated.

BACKGROUND

With the popularity of the Internet and social media, digital objects are generated at a rapid rate. These digital objects are usually multimedia, e.g., videos, images, audio files, texts, and a combination thereof. Annotation of the digital objects improves their searchability. By annotation, a digital object is tagged with metadata for describing the digital object, such as one or more keywords. Although searching for desired object(s) in a pool containing a large number of digital objects is made efficient by annotation, annotating a large number of digital objects is a technical challenge in its own weight.

Generally, machine learning algorithms are used in classifying digital objects for annotation. Initial classifier training is needed for intelligent cognitive systems. Digital objects that are initially used for training a classifier are first manually annotated by human annotation. Human annotation is undoubtedly a time-consuming costly process. It is desirable if human effort can be reduced in annotation. More concretely, it is preferable if a smaller number of digital objects from a pool of digital objects are selected to be human-annotated for training the classifier. However, most of existing techniques in annotation, such as the techniques proposed in CN104142912A, CN102999516A and US2010/0076923A1, are targeted to another aspect of increasing annotation accuracy of the classifier under the assumption that the available training samples are already annotated. There is a need in the art for a technique that reduces or minimizes the number of digital objects selected for human annotation.

SUMMARY OF THE INVENTION

A first aspect of the present invention is to provide a computer-implemented method for annotating a batch of original samples.

In the method, a first subset of original samples is selected from the batch for human annotation to yield human-annotated samples. The first subset is determined by optimizing the first subset in a sense of minimizing a difference between an entropy mean of the first subset and an entropy mean of the batch. The entropy mean of any set of original samples is computed by averaging entropy values of the original samples belonging to the aforementioned set. After the human-annotated samples are obtained, the original samples belonging to the selected first subset are removed from the batch. The human-annotated samples are used as training data to configure at least an annotation process for annotating an input sample to yield an annotated output sample. The annotation process after configuration is used for annotating any original sample remaining in the batch.

Preferably, the human-annotated samples are also used as training data to configure a check process for verifying annotation accuracy of the annotated output sample. In

addition, an annotate-and-check process is performed on any original sample remaining in the batch. The annotate-and-check process comprises the following steps. An individual original sample remaining in the batch is annotated by the annotation process to yield an individual machine-annotated sample. Annotation accuracy of the individual machine-annotated sample is verified by the check process. If the individual machine-annotated sample is verified to be accurate in annotation, the individual original sample is removed from the batch; otherwise, the individual machine-annotated sample is discarded. An optional step is to generate a verification result for the individual original sample. The verification result includes the individual original sample, the individual machine-annotated sample, and an indication of whether the individual machine-annotated sample is accurate. If the batch is not empty after the annotate-and-check process is performed, an update process is performed.

In one embodiment of the update process, a second subset of original samples is selected from the batch for human annotation to yield additional human-annotated samples. After the additional human-annotated samples are obtained, the original samples belonging to the selected second subset are removed front the batch. The additional human-annotated samples are used as additional training data to update the annotation process and the check process. If the batch is not empty after the update process is performed, the annotate-and-check process is repeated.

In another embodiment of the update process, the annotation process and the check process are updated according to one or more verification results obtained in the annotate-and-check process. In particular, all or part of the one or more of the verification results are used as additional training data to update the annotation process and the check process. After the update process is completed, the annotate-and-check process is repeated.

A second aspect of the present invention is to provide a computer-implemented method for annotating a group of original samples. The method comprises clustering the original samples in the group so as to partition the group into one or more clusters of original samples. Each cluster of original samples is annotated according to any embodiment of the method as set forth in the first aspect of the present invention.

Other aspects of the present invention are disclosed as illustrated by the embodiments hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a flowchart of annotating a batch of original samples in accordance with the present invention.

FIGS. **2**A and **2**B provide an example for illustrating the flow of processing in annotating the batch of original samples, where FIG. **24** depicts the first round of processing and FIG. **2**B depicts the second round of processing.

DETAILED DESCRIPTION

The following definitions are used herein in the specification and appended claims. “A sample” means a digital object. The digital object is a non-physical digital content in a computer environment. In most cases, the digital object is a multimedia content, such as a video, an image, an audio file, a text or a textual document, or a combination thereof. “An original sample” means a raw sample that is not annotated or is only pre-annotated. “Pre-annotation” is different from “annotation” in the following sense. For an original sample that is not annotated, the original sample does not contain any annotation message in association with the original sample. The original sample is the raw sample. For an original sample that is pre-annotated, the raw sample is associated with a first annotation message to form the original sample but the first annotation message is to be replaced by a second annotation message by a certain annotation process. The first annotation message may be used, for example, as an input to the annotation process so as to improve the first annotation message in annotation description and to thereby yield the second annotation message. In one practical example, the first annotation message is examined by a person to prepare the second annotation message with a more accurate description to the original sample in human annotation. "An annotated sample" means a resultant sample that is obtained by annotating an original sample. The annotated sample is formed by associating an annotation message to the raw sample in the original sample. Usually, the annotated sample is the raw sample tagged with the annotation message, or is represented by a data structure at least including the raw sample as one field and the annotation message as another field. For the annotated sample, it can be classified as a human-annotated sample or a machine-annotated sample. "A human-annotated sample" means an annotated sample obtained by human annotation of an original sample. "A machine-annotated sample" means an annotated sample whose annotation message is determined entirely by computer processing.

A first aspect of the present invention is to provide a computer-implemented method for annotating a batch of original samples. In the method, a subset of the batch is selected for human annotation. In the selection of the subset, human annotation is focused only on base cases and special cases of the original samples whereas machine annotation is used to annotate remaining original samples, thus advantageously minimizing or at least reducing the number of samples for human annotation. The Inventors have found that the base cases and the special cases can be identified according to art entropy value of each original sample. The method is illustrated with an aid of FIG. **1**, which depicts a flowchart of annotating a batch of original samples **105**.

An exemplary embodiment of the method is elaborated as follows.

In a step **110**, a first subset of original samples is selected from the batch **105**. Generally, a pre-determined fraction of the number of original samples in the batch **105** is selected for the first subset. However, it is not always the case, for example, when the number of original samples for human annotation is required to be upper-bounded due to resource limitation. The original samples in the first subset are used for human annotation to yield human-annotated samples (step **115**). In the step **110**, the first subset of original samples is advantageously determined by optimizing the first subset in a sense of minimizing a difference between an entropy mean of the first subset and an entropy mean of the batch. The entropy mean of any set of original samples is computed by averaging entropy values of the original samples belonging to the aforementioned set. The entropy value of an individual original sample is obtained through the following four steps.

First, split the individual original sample into plural constituent elements $\{y_j\}$. The constituent elements belong to the same type of feature. As illustrative examples, for four samples that are respectively a text, an image, a video and an audio signal, the corresponding feature types may be chosen to be a word, a sub-image, a key frame, and a time/frequency component of the audio signal, respectively.

Second, identify distinct constituent elements $\{x_i\}$ from $\{y_i\}$ such that each element in $\{y_j\}$ is also found in $\{x_i\}$.

Third, estimate $P(x_i)$, a probability of x_i, according to the number of one or more constituent elements in $\{y_j\}$ equal to x_i. In particular, $P(x_i)$ is estimated as the relative frequency of occurrence of x_i over the constituent elements $\{y_j\}$.

Four, compute the entropy value of the individual original sample as—$\Sigma_i P(x_i) \log_b P(x_i)$ where b is a base. Practically and preferably in the implementation of the disclosed method, b=2 is used.

An example is provided as follows for illustrating the computation of the entropy value of the individual original sample. Consider a sample that is a string "cat hat bat". The string can be regarded as a data set {cat, hat, bat}. The feature type is chosen to be an English letter. Hence, each constituent element of the sample is an English letter. Note that spaces in the string are excluded to be constituent elements. It follows that the sample is split into 9 constituent elements {c, a, t, h, a, t, b, a, t}, regarded as $\{y_j\}$ above with j=1, . . . , 9. There are 5 distinct constituent elements {a, t, c, h, b}, regarded as $\{x_i\}$ above with i=1, . . . , 5. By counting: $P(x_1)$ for "a" is estimated to be $P(x_1)=3/9=1/3$; $P(x_2)$ for "t" is estimated to be 1/3; and $P(x_5)$ for "b" is estimated to be 1/9. The entropy of letter "a" is computed by—$P(x_1) \log_2 P(x_1)=0.52$, the entropy of letter "b" is computed by—$P(x_5) \log_2 P(x_5)=0.35$. We say that letter "b" is less informative than letter "a" in this case since the entropy of "b" is lower than that of "a". The implication is that, if letter "b" is given as a part of input, it can be inferred that the input is very likely to be the word "bat". On the other hand, if letter "a" is given as a part of input, one has no idea on what the input has been. In addition, the entropy of a word is the sum of individual entropies of the letters of the word. The entropy mean of the whole data set is the sum of entropies of all the words in the string and then divided by the number of words (3 in this example). If a picture is used as another sample, the picture can be transformed to a grey-scale picture and can be divided into small blocks (i.e. sub-images). When each block is small enough, each small block of the picture can be regarded as a letter of a word in entropy computation.

The advantage of minimizing the entropy-mean difference between the first subset and the batch **105** in the selection of the first subset is evidenced as follows. The entropy value of the individual original sample is a measure of an amount of information of this sample. By finding the first subset where the difference between the entropy means of the first subset and of the batch **105** is minimized or relatively small over all possible candidate subsets of the batch, the amounts of information for both the first subset and the batch **105** are likely to be close. It follows that the first subset is likely to contain original samples representative to all the original samples in the batch **105**. It follows that machine learning and classifier training based on these representative original samples and resultant human-annotated samples is less likely to be misguided. These representative original samples form "the base cases" as mentioned above.

After the human-annotated samples are obtained in the step **115**, the original samples belonging to the selected first subset are removed from the batch **105**. Removing these original samples from the hatch **105** is simply an indication that these original samples have been annotated and do not require machine annotation.

The human-annotated samples are used as training data to configure at least an annotation process for annotating an input sample to yield an annotated output sample (step **120**). The annotation process after configuration is used in step **140** for annotating any original sample remaining in the batch **105'**. (The reference numeral **105'** is used instead of **105** in order to indicate that the batch **105'** may have been reduced in size when compared to the original batch **105** at the beginning.). Usually, the annotation process uses a machine-learning algorithm to classify the input sample. The machine-learning algorithm may be selected from a named-entity recognition (NER) classifier, a support vector machine (SVM) classifier and a neural network. In the art, there are NER systems that use linguistic grammar-based techniques as well as statistical models, i.e. machine learning. Hand-crafted grammar-based systems typically obtain better precision, but at the cost of lower recall and months of work by experienced computational linguists. Statistical NER systems typically require a large amount of manually annotated training data. Semi-supervised approaches may be used to avoid part of the annotation effort. Many different classifier types have been used in the art to perform machine-learned NER, with conditional random fields being a typical choice.

Generally, a selection process is used in the step **110** for selecting the first subset of original samples from the batch **105**.

In one embodiment of the selection process, a candidate subset of original samples is selected from the batch **105**. The entropy value of each original sample in the candidate subset is then computed. The entropy mean of the candidate subset is thereby computed by averaging the entropy values of original samples that belong to the candidate subset. The entropy mean of the batch of original samples **105** is similarly computed. By iteration, the candidate subset is iteratively improved or refined in a direction of minimizing a difference between the entropy mean of the candidate subset and the entropy mean of the batch **105**. Finally, the first subset is given by the candidate subset after a certain number of iterations. The number of iterations may be a pre-determined one. Alternatively, the iteration may be stopped when an incremental reduction of the entropy mean is less than a certain pre-determined threshold.

In another embodiment of the selection process, plural candidate subsets of original samples are selected front the batch **105**. The candidate subsets may be mutually non-overlapping or not. For each individual candidate subset, the entropy value of each original sample in the individual candidate subset is computed. The entropy mean of the individual candidate subset is computed by averaging the entropy values of original samples that belong to the individual candidate subset. The entropy mean of the batch **105** is similarly computed. Finally, among all the candidate subsets, the particular candidate subset having the entropy mean closest to the entropy mean of the batch **105** is selected to be the first subset.

Additional embodiments of the method are elaborated as follows.

It is desirable if annotation accuracy of machine-annotated samples generated by the annotation process in the step **140** is verified such that those machine-annotated samples not accurate in annotation can be identified and thereby discarded. In addition to having the annotation process for annotating the input sample to yield the annotated output sample, preferably a check process for verifying annotation accuracy of the annotated output sample is also used. Particularly, the human-annotated samples generated in the step **115** are also used as training data to configure the check process (step **130**). The check process may use a machine-learning algorithm selected from a NER classifier, a SYM classifier and a neural network. Alternatively, the check process may use an algorithm based on regular expressions. Yet in another option, the annotation process and the check process use a same threshold-based machine-learning algorithm but employ different thresholds.

By incorporating both the annotation process and the check process, an annotate-and-check process **160** is formed and is performed on any original sample remaining in the batch **105'**. The annotate-and-check process **160** comprises the following steps. An individual original sample remaining in the batch **105'** is annotated by the annotation process to yield an individual machine-annotation sample (the step **140**). Annotation accuracy of the individual machine-annotated sample is verified by the check process (step **150**). Optionally, a verification result **151** for the individual original sample is generated in the step **150**. One use of the verification result **151** is in an update process to be detailed soon. The verification result **151** includes the individual original sample, the individual machine-annotated sample, and an indication of whether the individual machine-annotated sample is accurate. If the individual machine-annotated sample is verified to be accurate in annotation in the step **150**, then the individual original sample is removed from the batch **105'**, or else the individual machine-annotated sample is discarded (step **155**). Note that the discard of the individual machine-annotation sample implies that the individual original sample is required to be re-annotated. The annotate-and-check process **160** is performed on all the original samples in the batch **105'**. Thereafter, the batch of remaining original samples requiring re-annotation is designated by reference **105"** for convenience.

If the batch **105"** is not empty, an update process is performed. Herein it is provided with two options of the update process.

In a first option of the update process **171**, a second subset of original samples is selected from the batch **105"** by performing the step **110** again. Preferably, the selection process used for selecting the first subset is also used for selecting the second subset. The second subset of original samples is used for human annotation to yield additional human-annotated samples by performing the step **115** again. Following the approach mentioned above in identifying the base cases, one can find that the original samples in the second subset are "the special cases" as mentioned above. The additional human-annotated samples are used as additional training data to update the annotation process and the check process in the steps **120** and **130**, respectively. After the additional human-annotated samples are obtained, the original samples belonging to the selected second subset are removed from the batch **105"**. If the batch **105'** (after the step **110** is performed on the hatch **105"**) is not empty after the update process is completed, then the annotate-and-check process **160** is repeated for the batch **105'**. If the batch **105'** is empty after completion of the update process, it means that all the original samples originally in the batch **105"** were already selected for human annotation during performing the step **110**. This situation may happen if the number of original samples originally in the batch **105"** is already very low, e.g., less than a pre-determined small integer such as 2.

In a second option of the update process **172**, a collection **152** having one or more verification results, each being the individual verification result **151**, is first obtained. All or part of the one or more verification results in the collection **152** are selected and directly used as additional training data to update the annotation process and the check process. Human annotation is not involved in the update process. Thus, the second option of the update process **172** has an advantage over the first option **171** in that a human personnel for human annotation is not required to be standby over the entire course of machine annotation.

It is possible to benchmark quality of annotating the batch of original samples **105**. The quality of annotating the batch **105** is obtained by processing the original samples belonging to the selected first subset with the annotate-and-check process **160** and then checking the collection **152** of the one or more verification results with the human-annotated samples. The benchmarking is preferably performed right after the annotation process and the check process are initially configured by the human-annotated samples, for an advantage that whether or not further improvement on the annotate-and-check process **160** may be required before the original samples in the batch **105'** are annotated. If it is found that further improvement is required, one may expand the first subset of original samples, and repeat performing human annotation **115** and configuring the annotation process and the check process in the steps **120**, **130**.

One example is provided for illustrating the execution of the disclosed method by considering a case of annotating 100 original samples (as the hatch of original samples **105**). For the purpose of illustration, it is assumed that the 100 original samples are not pre-annotated, the first option of the update process **171** is used, and two rounds of processing are adequate to annotate all the 100 original samples. The execution of the method for the second option of the update process **172** is similar and is not repeated. FIGS. **2**A and **2**B depict the flows of processing for the first and second rounds, respectively.

Refer to FIG. **2**A, which depicts the first round of processing. A batch of 100 original samples **200** is partitioned into a first plurality of 10 original samples selected for human annotation **210** and a second plurality of 90 original samples for machine annotation **220** (corresponding to the step **110**). The first plurality of original samples **210** are human-annotated (corresponding to the step **115**) to yield a third plurality of 10 human-annotated samples **211**. The third plurality of human-annotated samples **211** is used to train an annotation process (corresponding to the step **120**) and a check process (corresponding to the step **130**). After the annotation process and the check process are trained, the second plurality of original samples **220** are machine-annotated by the annotation process (corresponding to the step **140**) to yield a fourth plurality of 90 machine-annotated samples **221**. The fourth plurality of machine-annotated samples **221** is processed by the check process to verify each machine-annotated sample therein (corresponding to the step **150**). As a result of verification, the fourth plurality of machine-annotated samples **221** is partitioned into a fifth plurality of 50 machine-annotated samples determined to be correctly annotated **231**, and a sixth plurality of 40 machine-annotated samples that are determined to be erroneously annotated **232**. The first around of processing ends, and 60 out of 100 original samples are correctly annotated. The remaining 40 original samples, collectively corresponding to the sixth plurality of erroneous machine-annotated samples, form a seventh plurality of 40 original samples **240** to be handled in the second round of processing. The sixth plurality of erroneous machine-annotated samples **232** is discarded.

Refer to FIG. **2**B, which depicts the second around of processing. The seventh plurality of original samples **240** is partitioned into an eighth plurality of 4 original samples for human annotation **250** and a ninth plurality of 36 original samples for machine annotation **260** (corresponding to a second-time execution of the step **110**). The eighth plurality of original samples **250** is human-annotated (corresponding to the second-time execution of the step **115**) to form a tenth plurality of 4 additional human-annotated samples **251** to be used as additional training data to update the annotation process and the check process (corresponding to the steps **120** and **130**). After the annotation process and the check process are updated, the ninth plurality of original samples **260** is annotated by the annotation process (corresponding to the step **140**) to give an eleventh plurality of 36 machine-annotated samples **261**. By the checking process (corresponding to the step **150**), all the 36 samples in the eleventh plurality of machine-annotated samples **261** are determined to have accurate annotation. Hence, a twelfth plurality of 36 machine-annotated samples determined to be correctly annotated **271** is obtained. At the end of the second round of processing, all the 100 original samples originally in the batch **200** have been annotated. The set of 100 annotated samples consists of the third plurality of 10 human-annotated samples **211**, the fifth plurality of 50 machine-annotated samples determined to be correctly annotated **231**, the tenth plurality of 4 additional human-annotated samples **251**, and the twelfth plurality of 36 machine-annotated samples determined to be correctly annotated **271**.

A second aspect of the present invention is to provide a computer-implemented method for annotating a group of original samples based on the method disclosed above according to the first aspect.

Refer to FIG. **1** again. A group of original samples **102** is to be annotated. The original samples in the group **102** are first clustered in a step **180** so as to partition the group **102** into one or more clusters of original samples **103**. Each of the one or more clusters **103** is annotated according to any embodiment of the method disclosed above according to the first aspect of the present invention, where each cluster of original samples is treated as the batch of original samples **105**.

In the step **180**, K-mean clustering may be used to cluster the original samples in the group **102**.

In practical implementation, it is possible that each original sample in the group **102** is provided with pre-annotation data. A data structure for an individual original sample in the group **102** may be formed by including the individual original sample and the pre-annotation data thereof. A plurality of data structures for all the original samples in the group **102** is thereby obtained. In the step **180**, K-mean clustering of the plurality of data structures may be performed to cluster the original samples in the group **102**.

In annotating an individual cluster of original samples, the number of the original samples in the first subset selected in the step **110** is a usually pre-determined fraction of the number of the original samples in the aforementioned individual cluster. In one option, the pre-determined fraction is unique for all the one or more clusters **103**.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A computer-implemented method for annotating a batch of original samples, comprising:

selecting a first subset of original samples from the batch for human annotation to yield human-annotated samples, wherein the first subset is determined by optimizing the first subset in a sense of minimizing a difference between an entropy mean of the first subset and an entropy mean of the batch, and wherein an entropy mean of a set of original samples is computed by averaging entropy values of respective original samples belonging to said set;

after the human-annotated samples are obtained, removing the original samples belonging to the selected first subset from the batch;

using the human-annotated samples as training data to configure an annotation process for annotating an input sample to yield an annotated output sample, whereby the annotation process after configuration is used for annotating any original sample remaining in the batch;

using the human-annotated samples as training data to configure a check process for verifying annotation accuracy of the annotated output sample;

performing an annotate-and-check process on an individual original sample remaining in the batch, wherein the annotate-and-check process comprises:

annotating the individual original sample remaining in the batch by the annotation process to yield an individual machine-annotated sample;

verifying annotation accuracy of the individual machine-annotated sample by the check process; and

if the individual machine-annotated sample is verified to be accurate in annotation, then removing the individual original sample from the batch, else discarding the individual machine-annotated sample;

if the batch is not empty after the annotate-and-check process is performed, performing an update process, wherein the update process comprises:

selecting a second subset of original samples from the batch for human annotation to yield additional human-annotated samples;

using the additional human-annotated samples as additional training data to update the annotation process and the check process; and

after the additional human-annotated samples are obtained, removing the original samples belonging to the selected second subset from the batch;

and

if the batch is not empty after the update process is performed, repeating the annotate-and-check process.

2. The method of claim **1**, wherein each of the first and second subsets is a third subset of original samples selected from the batch, the third subset being determined by a selection process comprising:

selecting a candidate subset of original samples from the batch;

computing the entropy mean of the candidate subset; and

iteratively improving the candidate subset in a direction of minimizing a difference between the entropy mean of the candidate subset and the entropy mean of the batch, whereby the third subset is given by the candidate subset after a number of iterations.

3. The method of claim **1**, wherein each of the first and second subsets is a third subset of original samples selected from the batch, the third subset being determined by a selection process comprising:

selecting plural candidate subsets of original samples from the batch;

computing the entropy mean of each candidate subset; and

selecting, among all the candidate subsets, the candidate subset having the entropy mean closest to the entropy mean of the batch to be the third subset.

4. The method of claim **1**, wherein the annotation process uses a machine-learning algorithm selected from a named-entity recognition (NER) classifier, a support vector machine (SVM) classifier and a neural network.

5. The method of claim **1**, wherein the check process uses a machine-learning algorithm selected from a named-entity recognition (NER) classifier, a support vector machine (SVM) classifier and a neural network.

6. The method of claim **1**, wherein the check process uses an algorithm based on regular expressions.

7. The method of claim **1**, wherein the annotation process and the check process use a same threshold-based machine-learning algorithm but employ different thresholds.

8. A computer-implemented method for annotating a group of original samples, comprising:

clustering the original samples in the group so as to partition the group into one or more clusters of original samples; and

annotating each cluster of original samples according to the method of claim **1**.

9. The method of claim **8**, wherein K-mean clustering is used in the clustering of the original samples in the group.

10. The method of claim **8**, wherein:

each original sample in the group is provided with pre-annotation data;

the method further comprises forming a data structure for an individual original sample in the group by including the individual original sample and the pre-annotation data thereof, whereby a plurality of data structures for all the original samples in the group is obtained; and

K-mean clustering of the plurality of data structures is performed in the clustering of the original samples in the group.

11. The method of claim **8**, wherein:

in the annotating of an individual cluster of original samples, a number of the original samples in the first subset is a pre-determined fraction of a number of the original samples in the individual cluster; and

the pre-determined fraction is unique for all the clusters.

12. A computer-implemented method for annotating a batch of original samples, comprising:

selecting a first subset of original samples from the batch for human annotation to yield human-annotated samples, wherein the first subset is determined by optimizing the first subset in a sense of minimizing a difference between an entropy mean of the first subset and an entropy mean of the batch, and wherein an entropy mean of a set of original samples is computed by averaging entropy values of respective original samples belonging to said set;

after the human-annotated samples are obtained, removing the original samples belonging to the selected first subset from the batch;

using the human-annotated samples as training data to configure an annotation process for annotating an input sample to yield an annotated output sample, whereby the annotation process after configuration is used for annotating any original sample remaining in the batch;

using the human-annotated samples as training data to configure a check process for verifying annotation accuracy of the annotated output sample;

performing an annotate-and-check process on an individual original sample remaining in the batch, wherein the annotate-and-check process comprises the steps of:

(a) annotating the individual original sample remaining in the batch by the annotation process to yield an individual machine-annotated sample;

(b) verifying annotation accuracy of the individual machine-annotated sample by the check process, whereby a verification result for the individual original sample is generated, the verification result including the individual original sample, the individual machine-annotated sample, and an indication of whether the individual machine-annotated sample is accurate;

(c) if the individual machine-annotated sample is verified to be accurate in annotation, then removing the individual original sample from the batch, else discarding the individual machine-annotated sample; and

(d) repeating the steps (a)-(c) for each original sample in the batch, whereby one or more verification results are obtained;

and

if the batch is not empty after the annotate-and-check process is performed, performing an update process and then repeating the annotate-and-check process, wherein the update process comprises:

selecting all or part of the one or more of the verification results as additional training data to update the annotation process and the check process.

13. The method of claim **12**, wherein the first subset of original samples is determined by a selection process comprising:

selecting a candidate subset of original samples from the batch;

computing the entropy mean of the candidate subset; and

iteratively improving the candidate subset in a direction of minimizing a difference between the entropy mean of the candidate subset and the entropy mean of the batch, whereby the first subset is given by the candidate subset after a number of iterations.

14. The method of claim **12**, wherein the first subset of original samples is determined by a selection process comprising:

selecting plural candidate subsets of original samples from the batch;

computing the entropy mean of each candidate subset; and

selecting, among all the candidate subsets, the candidate subset having the entropy mean closest to the entropy mean of the batch to be the first subset.

15. A computer-implemented method for annotating a group of original samples, comprising:

clustering the original samples in the group so as to partition the group into one or more clusters of original samples; and

annotating each cluster of original samples according to the method of claim **12**.

16. The method of claim **15**, wherein K-mean clustering is used in the clustering of the original samples in the group.

17. The method of claim **15**, wherein:

each original sample in the group is provided with pre-annotation data;

the method further comprises forming a data structure for an individual original sample in the group by including the individual original sample and the pre-annotation data thereof, whereby a plurality of data structures for all the original samples in the group is obtained; and

K-mean clustering of the plurality of data structures is performed in the clustering of the original samples in the group.

18. The method of claim **15**, wherein:

in the annotating of an individual cluster of original samples, the number of the original samples in the first subset is a pre-determined fraction of the number of the original samples in the individual cluster; and

the pre-determined fraction is unique for all the clusters.

19. The method of claim **12**, further comprising:

benchmarking quality of annotating the batch of original samples by processing the original samples belonging to the selected first subset with the annotate-and-check process and then checking the one or more verification results with the human-annotated samples.

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